The Emerging Class of Double-faced White Dwarfs

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Outline

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- Result
- Summary

White Dwarf Classification

- White dwarfs can be classified based on their spectral features.
- DA: Hydrogen dominated atmosphere
  Balmer lines series
- DB: Neutral helium dominated atmosphere
  Neutral helium lines

Definition of Primary Symbols: Primary Spectral

Spectral Type	Characteristics
DA	Only Balmer lines; no He I or metals present
DB	He I lines; no H or metals present
DC	Continuous spectrum, no lines deeper than 5% in any part of the electromagnetic spectrum
DO	He II strong: He I or H present
DZ	Metal lines only; no H or He
DQ	Carbon features, either atomic or molecular, in any part of the electromagnetic spectrum

Edward, 1983, ApJ

- DA to DB transition:

"The DA to DB change happens because of two types of convection that bring inner helium to the surface:

Convective dilution($14000K < T_{eff} < 30000K$): The deep helium convection expands upwards, mixing helium into the surface.

Convective mixing(6000K$< T_{eff} < 14000K$): Later, surface hydrogen convection reaches down and dredges up(捞起) more helium.

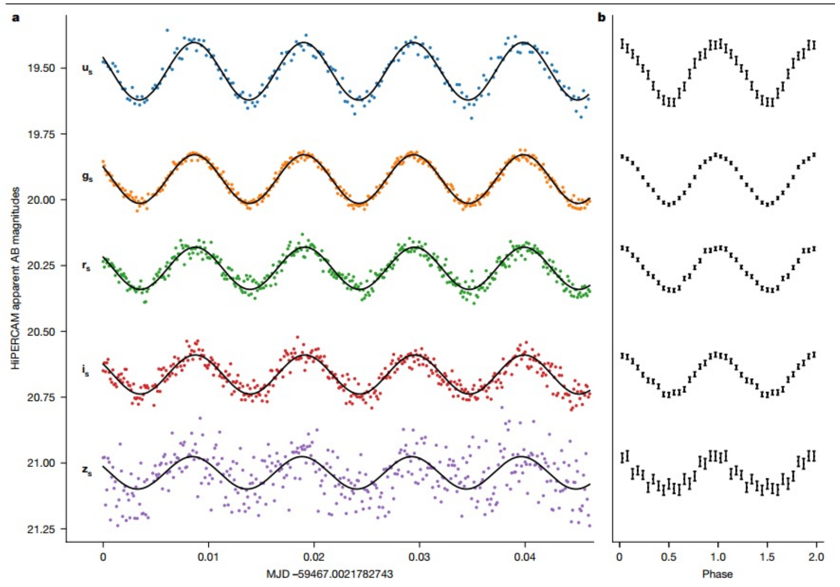
Both processes make the star's surface helium-rich, turning it from a DA to a DB."

Double-Face White Dwarfs

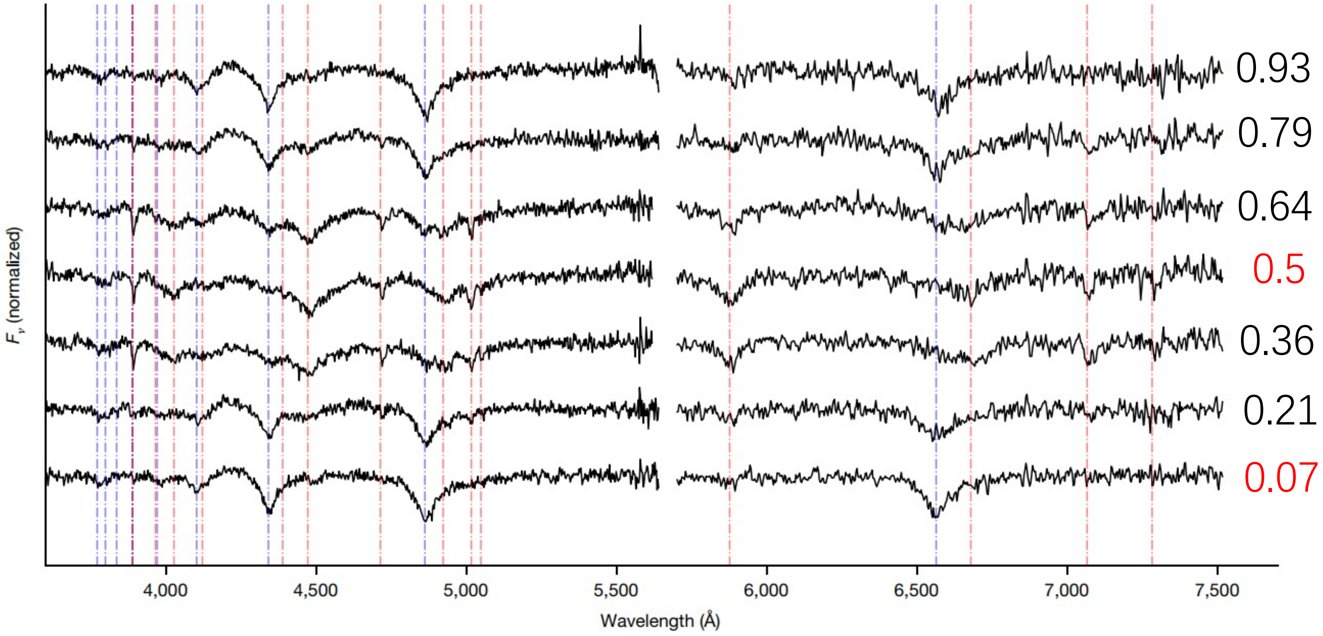
The internal convective processes previously in white dwarfs are typically expected to result in homogeneously mixed stellar surfaces.

However, several white dwarfs exhibit **inhomogeneous atmospheres**. These so-called **'double-faced' white dwarfs** show periodically varying between DA and DB as revealed by time-resolved spectra. The most extreme example is ZTF J203349.8+322901.1 (I. Caiazzo et al. 2023), in which the **hydrogen and helium lines completely vanish and reappear**, suggesting one side is dominated by hydrogen and the other by helium

Muti-band Light curve



Time-resolved Spectra



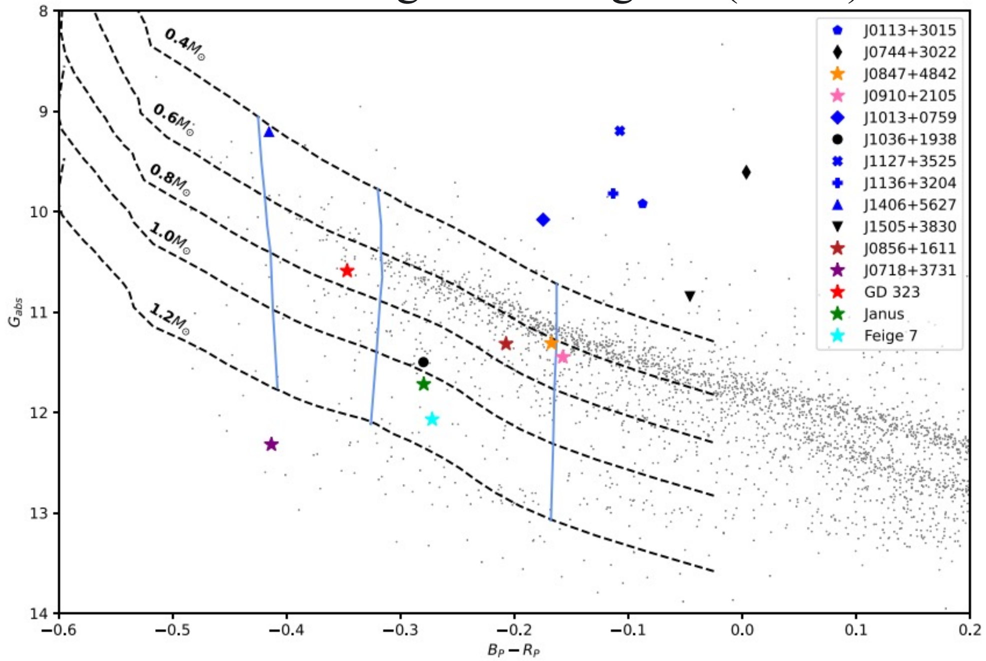
The Role of Magnetism in Double-faced White Dwarfs

- **Magnetism** is proposed to cause inhomogeneous atmospheres in white dwarfs by **inhibit convective processes**.
- The magnetic field, especially where it is stronger (e.g., **at the poles**), inhibits convection **more effectively**. This prevents the uniform mixing or dilution of elements across the stellar surface, thereby allowing distinct regions to maintain different chemical abundances (like **hydrogen-rich polar caps and helium-rich equatorial areas**) instead of forming a homogeneous atmosphere.
- When this scenario is combined with the **oblique rotator model**, as the white dwarf rotates, an observer alternately sees the hydrogen-rich polar and the helium-rich equatorial . In this way, the white dwarf exhibits a "two-faced" characteristic.

Result

Moss et al. (2025) performed time-series spectroscopy on potential double-faced white dwarf candidates drawn from SDSS (Genest-Beaulieu & Bergeron (2019)). This work newly confirmed two of these targets(J0847 and J0856). Combined with five previously known examples, this brings the total count of confirmed double-faced white dwarfs to seven as summarized.

Gaia color-magnitude diagram (CMD)



Moss, 2025, ApJ

Physical Parameters of the Known Double-faced White Dwarfs

Object	$T_{\rm eff}$ (K)	Mass ($M_\odot$)	$B_{\rm d}$ (MG)	Rotation Period (hr)	References
J0847+4842	14999	0.585	…	6.5 or 8.9	This work
J0856+1611	17574	0.773	1.5	5.7	This work, J. J. Hermes et al. (2017), F. Hardy et al. (2023)
J0910+2105	16746	0.778	0.55	7.7 or 11.3	A. Moss et al. (2024)
ZTF J203349.8+322901.1	~35800	~1.24	…	0.25	I. Caiazzo et al. (2023)
GD 323	26926	0.778	…	3.5	M. Kilic et al. (2020)
Feige 7	18381	1.077	39.45	2.18	F. Hardy et al. (2023), G. Jewett et al. (2024)
GALEX J071816.4+373139	33942	1.27	~8	0.18	S. Cheng et al. (2024), G. Jewett et al. (2024)

Result

Magnetism is proposed as the primary driver for the emergence of double-faced white dwarfs.(先描述表格和图) This class of objects exhibits a **mass distribution skewed towards higher values** than typical DB WDs. They also have a notably **higher incidence of strong magnetic fields** (most white dwarfs field strength typically in the range of 10^3 to 10^5 Gauss). These characteristics, strongly **support magnetism as the origin of their non-uniform atmospheres.**

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J0847+4842	14999	0.585	...	6.5 or 8.9
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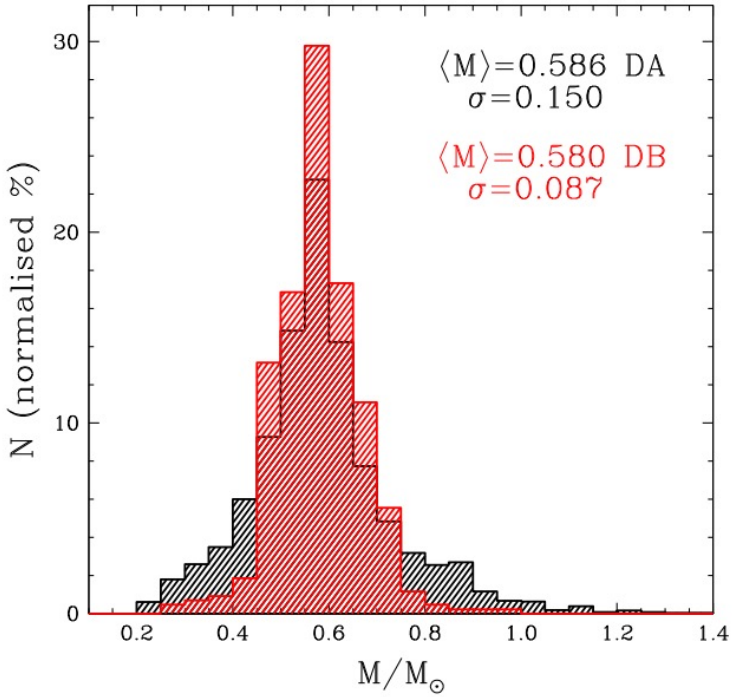
Mass Distribution of DA and DB



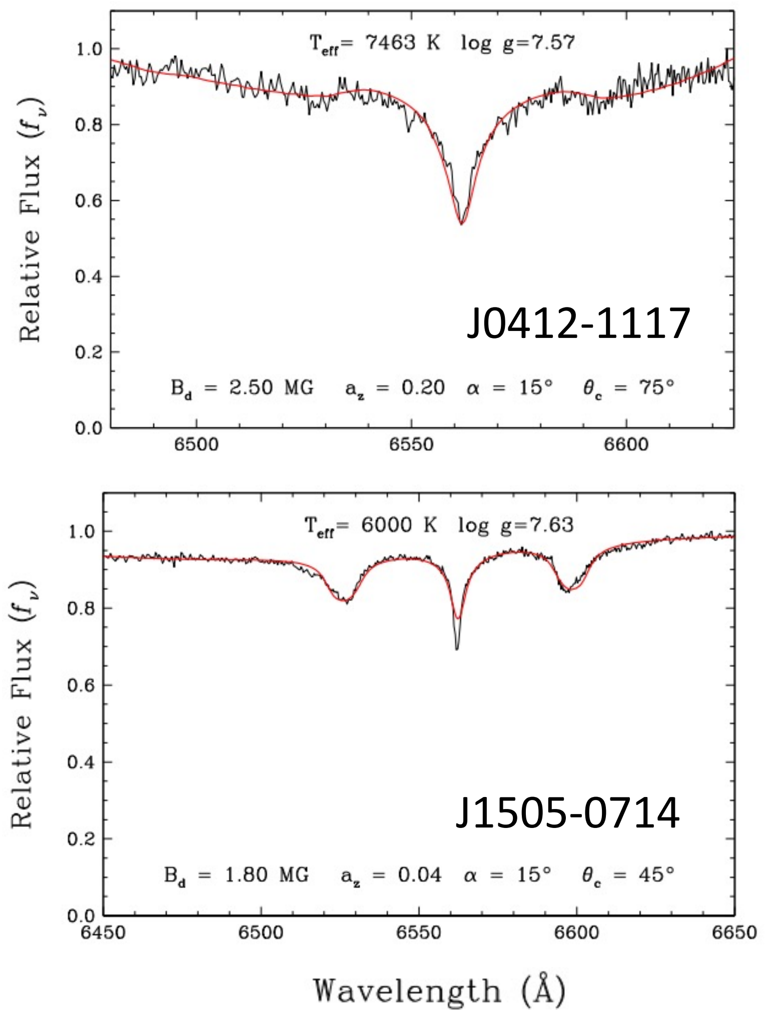
Tremblay, 2019, MN

DA white dwarfs in SDSS DR7
DB/DBA from SDSS DR12

Cooler Double-faced White Dwarfs

- Known double-faced WDs typically have Teff ~15000–36000 K, likely arising from magnetic fields influencing convective dilution (relevant ~14000–30000 K). Consequently, cooler DAs, normally undergoing convective mixing (dominant ~14,000–6,000 K), are also possible to develop inhomogeneous atmospheres if similarly influenced by magnetism.
- Evidence for these cooler counterparts, such as G160-51 and GD 175, is found. Homogeneous atmosphere models fail to explain their spectra without invoking a dense, cool (DC) companion. However, patchy-atmosphere models successfully interpret these spectra independently. This strongly suggests these objects are indeed the cooler double-faced WDs, confirming a broader population.

Patchy-atmosphere Fits to the Spectra



Sources Without Light Curve

Object	$T_{\rm eff}$ (K)	Mass ($M_\odot$)	$B_{\rm d}$ (MG)	Rotation Period (hr)
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J0847+4842	14999	0.585	...	6.5 or 8.9
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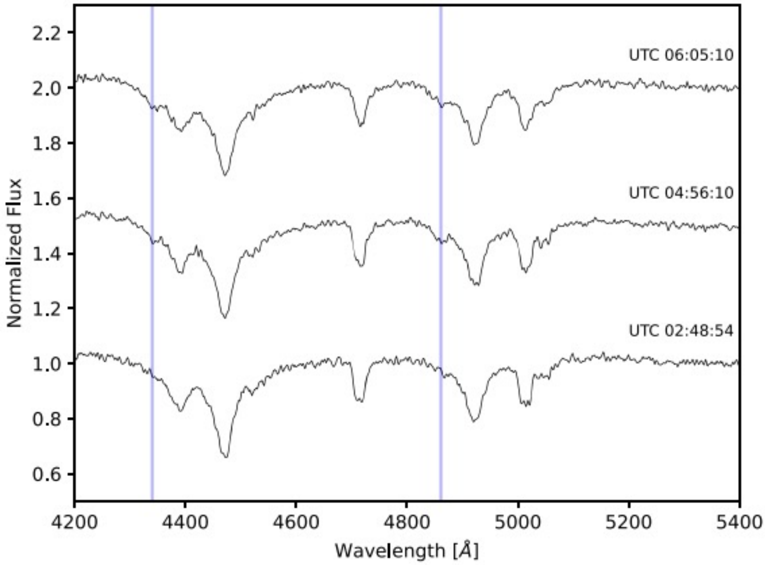
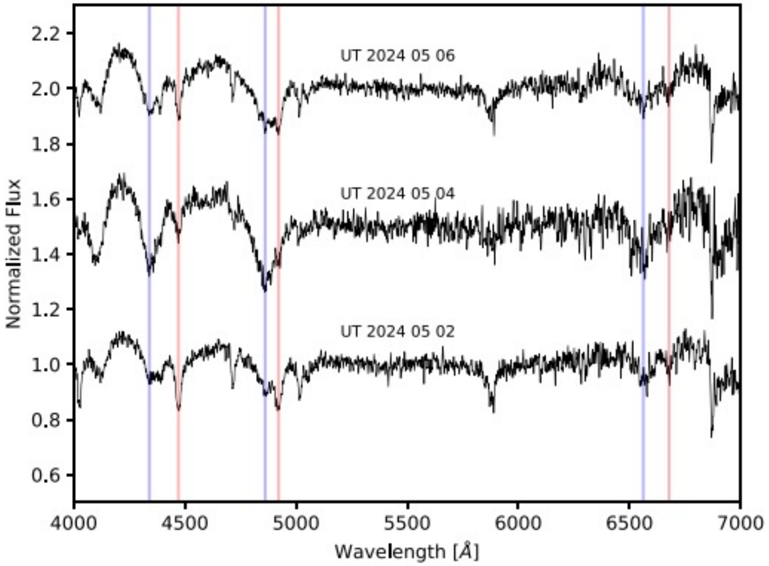
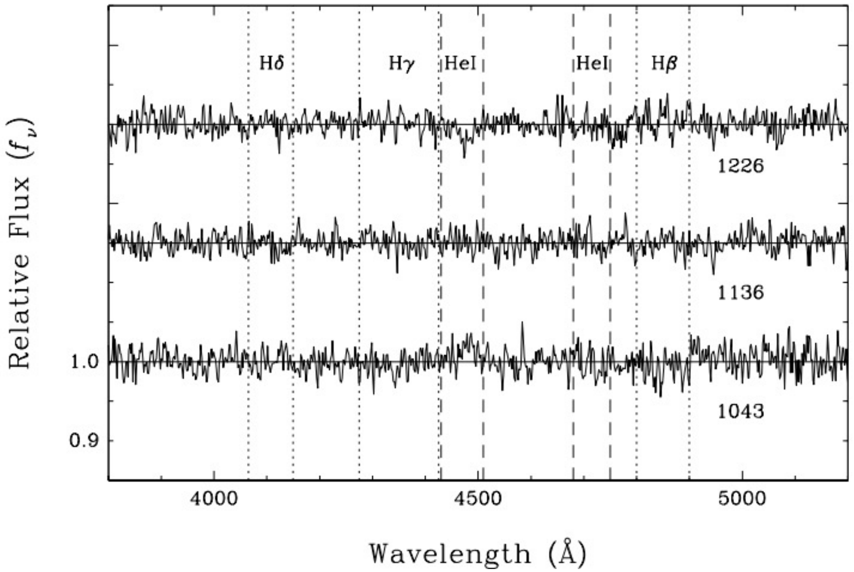
J0856+1611



J0847+4842

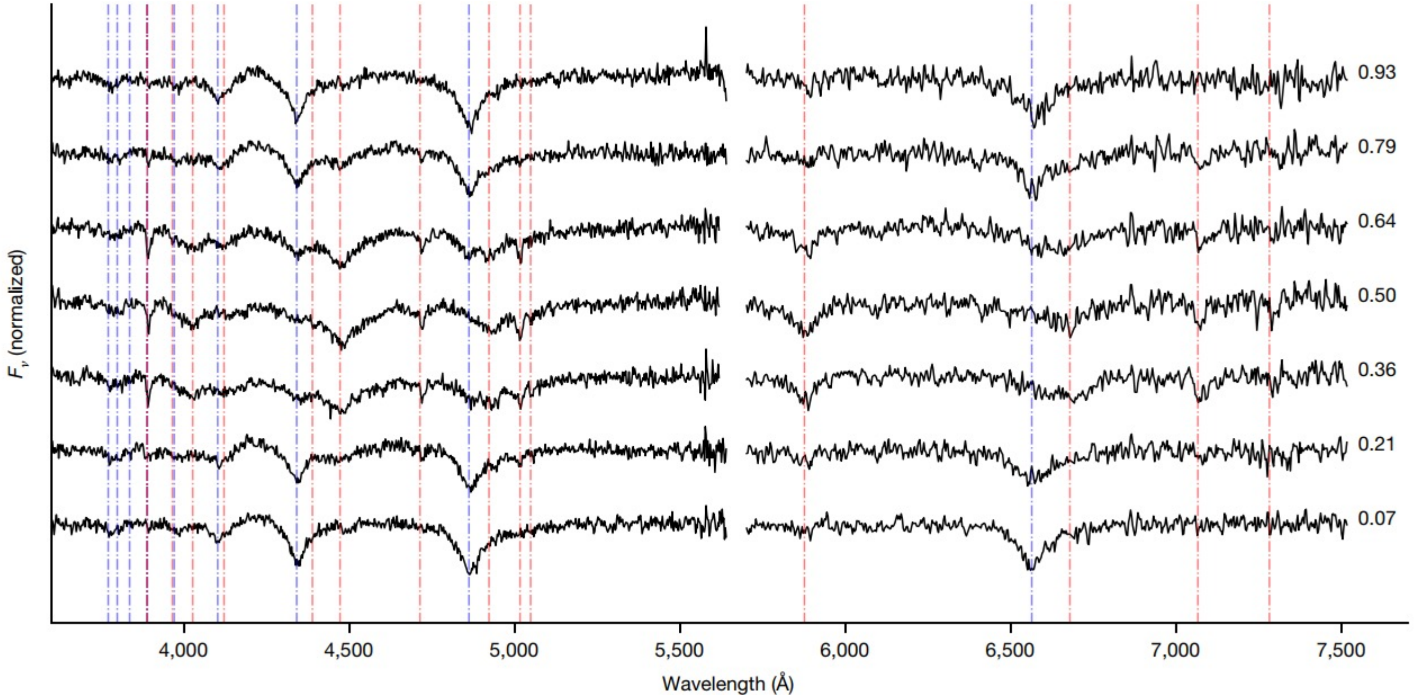


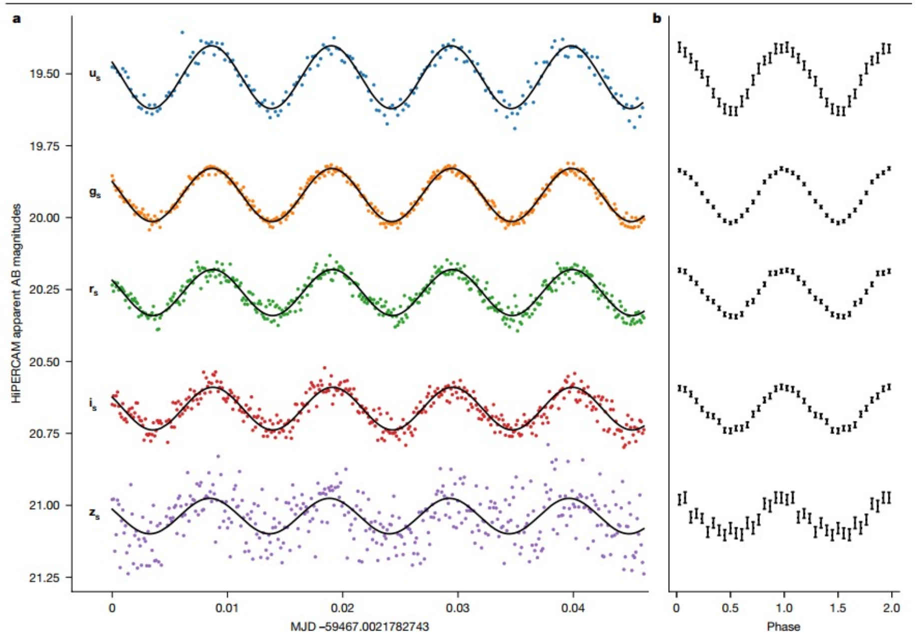
GD 323



ZTF J203349.8+322901.1

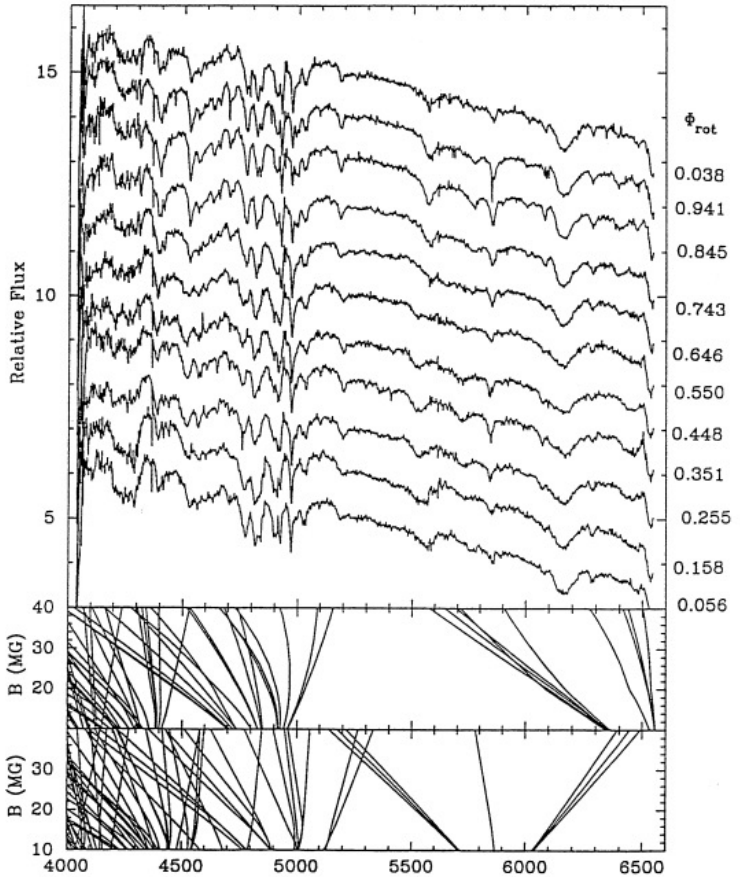
Object	T_{eff} (K)	Mass ($M_{\odot}$)	B_{d} (MG)	Rotation Period (hr)
ZTF J203349.8+322901.1	~35800	~1.24	...	0.25

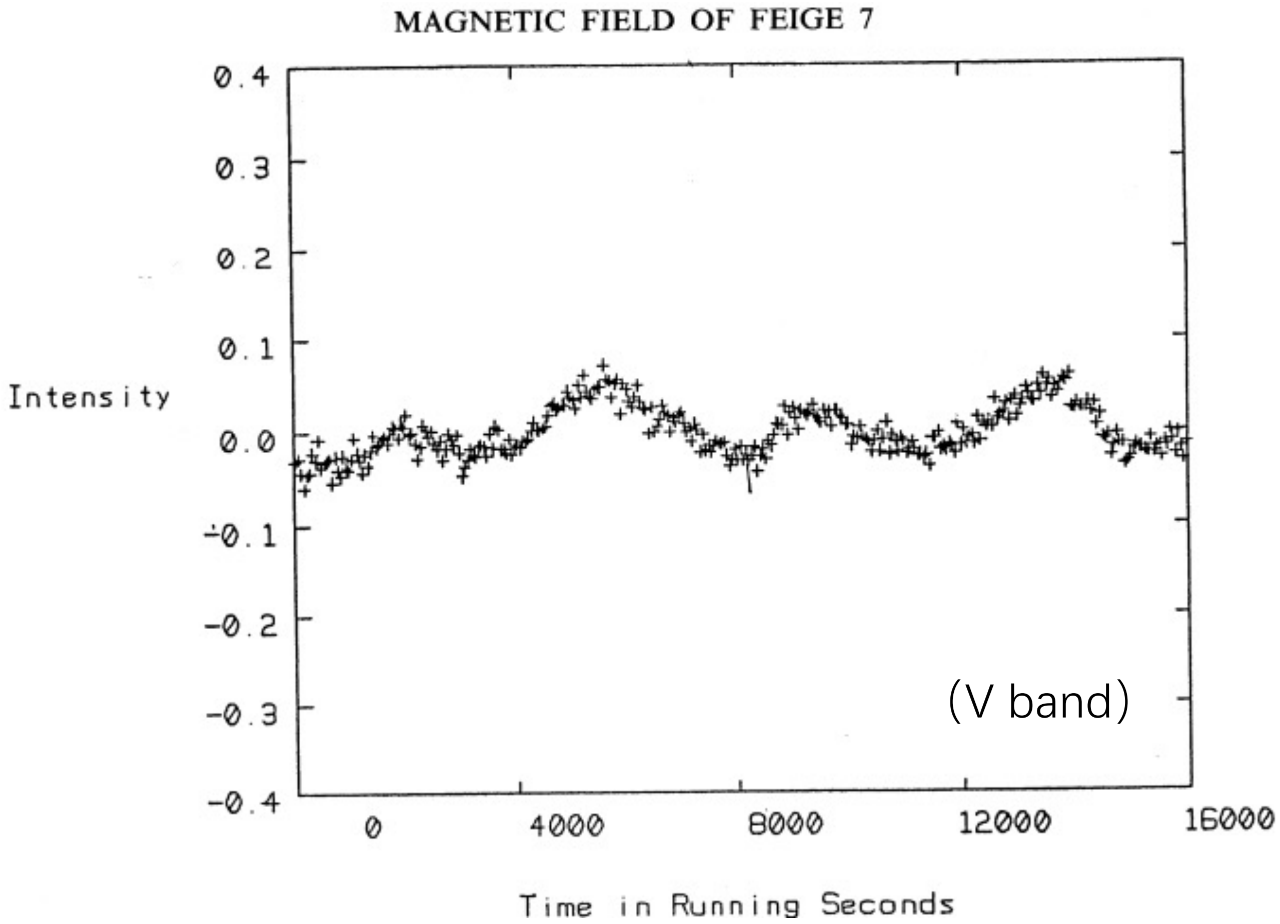




Feige 7

Object	T_{eff} (K)	Mass ($M_{\odot}$)	B_d (MG)	Rotation Period (hr)
Feige 7	18381	1.077	39.45	2.18





GALEX J071816.4+373139

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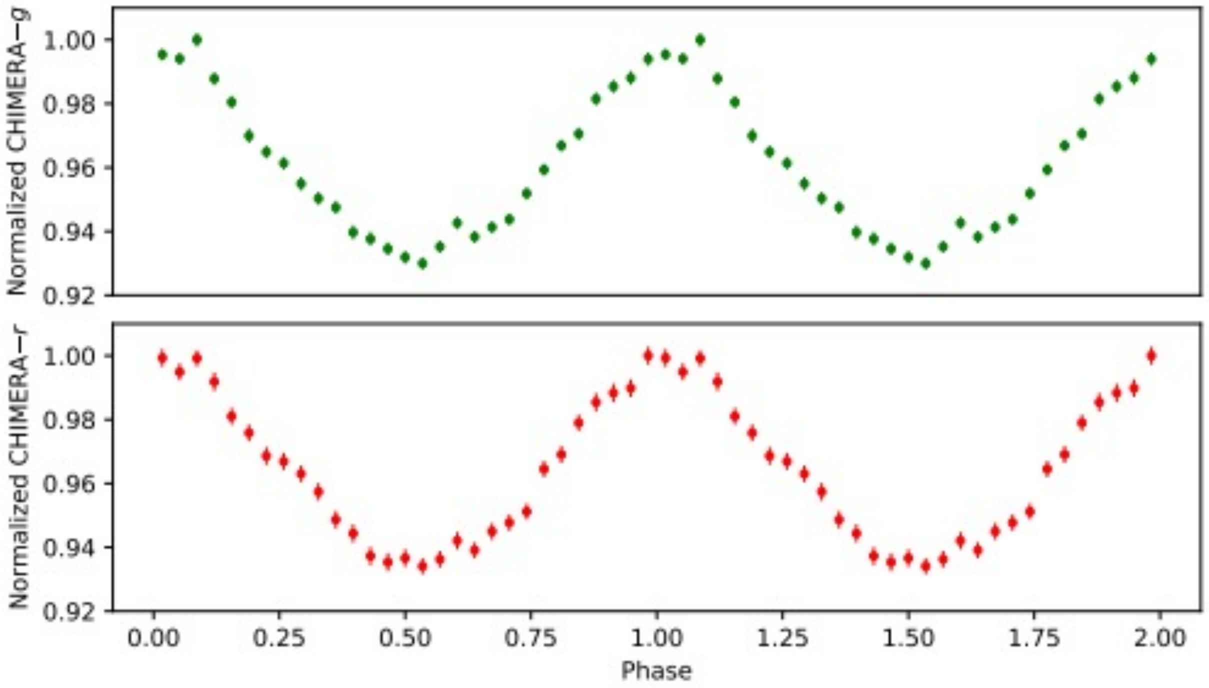
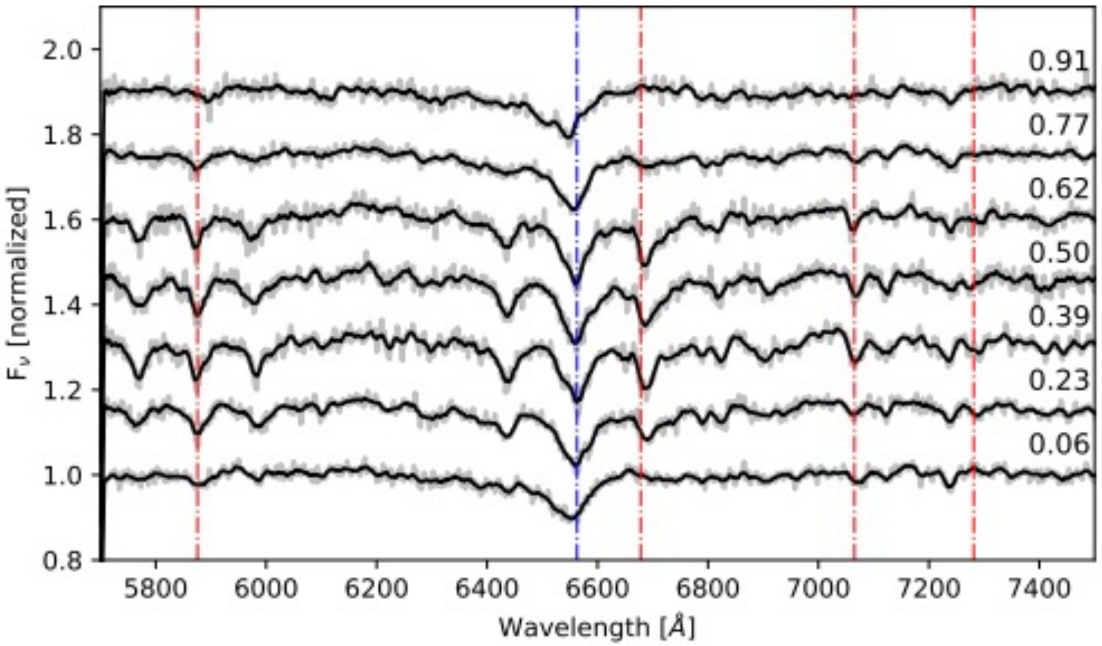
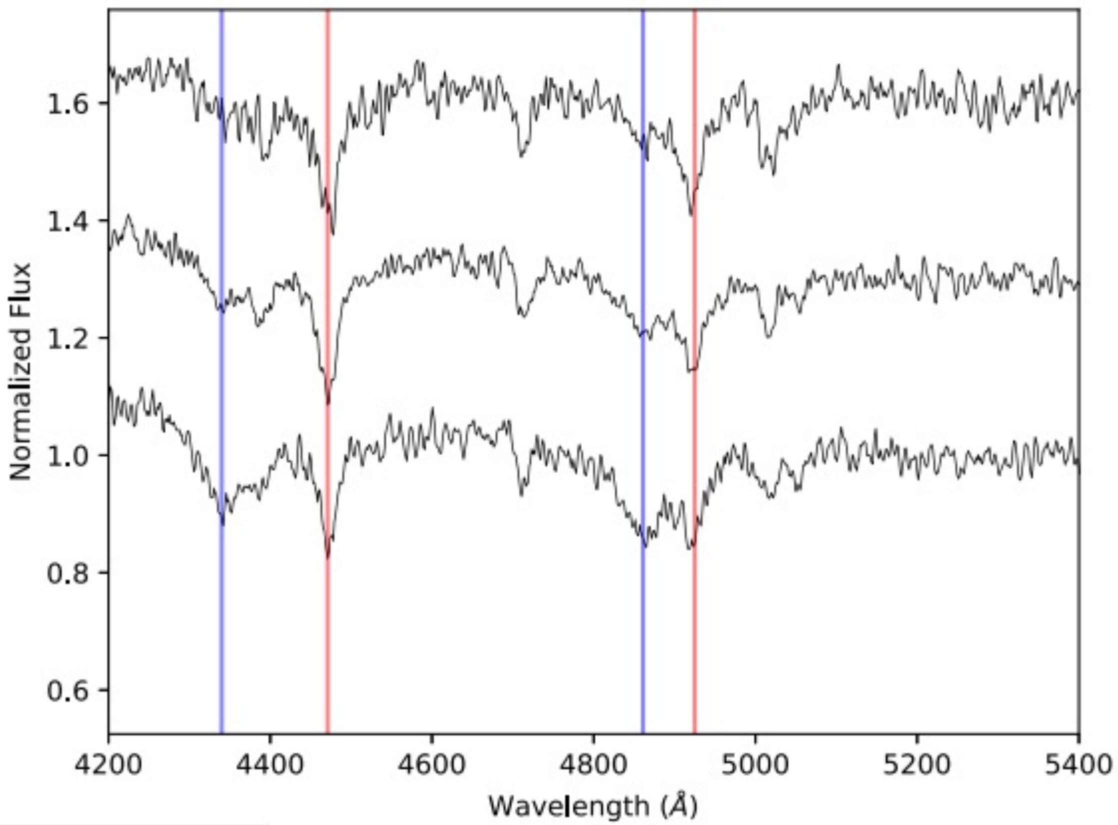
GALEX J071816.4+373139	33942	1.27	∼8	0.18



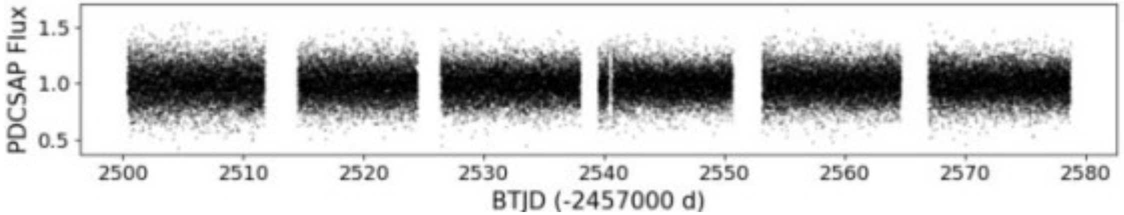


J0910+2105

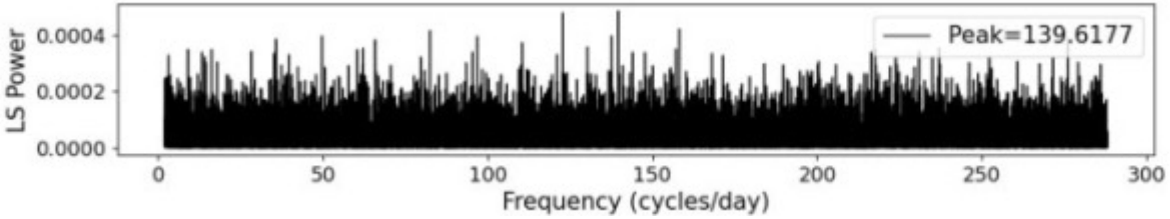
Object	$T_{\rm eff}$ (K)	Mass ($M_\odot$)	$B_{\rm d}$ (MG)	Rotation Period (hr)
J0910+2105	16746	0.778	0.55	7.7 or 11.3



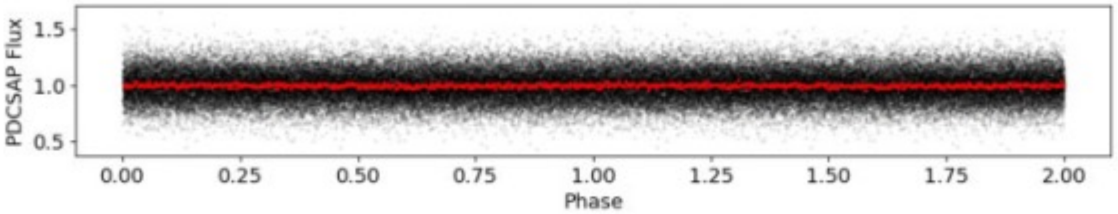
Light curve



Lomb–Scargle periodogram



Phase-folded light curve based on the highest peak in the periodogram



Summary

- **"Double-Faced" Class Defined**: Formally defined by patchy atmospheres due to magnetic fields influencing H/He mixing, distinct from typical WDs. Their rarity in DBAs mirrors magnetism's infrequency in He-WDs.
- **Temperature Range & Formation**: Hotter ones (Teff ~36,000–15,000 K) likely form via magnetically influenced convective dilution. Cooler counterparts (from convective mixing, ~14,000–6,000 K) are identified among cool magnetic DAs by shallower-than-expected Hα lines.
- **Magnetism as Driver**: Further modeling of magnetically influenced convection is key to confirm magnetism as the driving force for these inhomogeneities, even if fields aren't directly detected, potentially involving complex structures beyond a simple dipole.

That`s all.

对SDSS源后续时序光谱探测用到的设备

1. **阿帕奇角天文台 (Apache Point Observatory - APO)**:
    - **望远镜**: 3.5米望远镜
    - **光谱仪**: Kitt Peak Ohio State Multi-Object Spectrograph (KOSMOS)
    - *具体设置*: 使用了2英寸狭缝，蓝色色散元件，2x2分档。覆盖波长范围3800-6600 Å，分辨率4.7 Å。
2. **MMT天文台 (MMT Observatory)**:
    - **望远镜**: 6.5米望远镜
    - **光谱仪**: Blue Channel Spectrograph
    - *具体设置*: 使用了1.25英寸狭缝，500 线/毫米光栅，分辨率4.5 Å。
3. **北双子座望远镜 (Gemini North telescope)**:
    - **望远镜**: 8米望远镜
    - **光谱仪**: Gemini Multi-Object Spectograph (GMOS)
    - *具体设置*: 使用了B480光栅，1英寸狭缝，4x4分档。波长覆盖范围3555-7300 Å，分辨率6.3 Å。